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SEMI-ANNUAL TECHNICAL SUMMARY
for the period ending 31 March 1968

to

ADVANCED RESEARCH PROJECTS AGENCY

RESEARCH ON ELECTROMAGNETICS FOR PROJECT DEFENDER
ARPA Order No. 529 Program Code No. 5730

JUL 30 1968

Report
R-1295.6-68

for
Office of Naval Research
Contract Nonr-839(38)

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POLYTECHNIC INSTITUTE OF BROOKLYN

76

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for the period ending 31 March 1968

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ARPA Order No. 529

Program Code No. 5730

Date of Contract: 1 February 1964

Expiration Date: 31 August 1969

Report
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for
Office of Naval Research
Contract Nonr-839(38)

Submitted by: Rudolf G. E. Hutter
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PIBMRI-1295.6-68

ACKNOWLEDGEMENT

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ABSTRACT

This report contains a compilation of abstracts of papers which were either accepted for publication or were published. The papers are on the subjects of Fluid Dynamics, Electromagnetics and Plasmas. The work described was carried out under an ARPA contract, Order No. 529. This summary also contains a listing of papers submitted to journals, lectures, internal reports and staff activities.

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I. INTRODUCTION

The Polytechnic Institute of Brooklyn is conducting a broad interdisciplinary theoretical and experimental research program in plasma aerodynamics, electromagnetic scattering theory and experimental plasma research applicable to both the immediate and long-range interests of the ARPA Ballistic Missile Defense Program. Emphasis is being placed on fluid dynamics, electromagnetic radiation and their interaction with media characteristic of the ballistic missile defense environment.

II. SUMMARY OF RESEARCH

In this section are presented abstracts of technical papers which have been either published or accepted for publication during the reporting period covered by this report.

A. FLUID DYNAMICS

S. Lederman and D. S. Wilson, "Comment on Precursors in a Pressure Driven Shock Tube", AIAA Journal, Vol. 6, No. 2, p. 382, February 1968.

This note represents comments made by Professor H. Weymann on a recent publication of Lederman and Wilson entitled "Microwave Resonant Cavity Measurement of Shock Produced Electron Precursors". Professor Weymann misinterpreted the experimental data presented by Lederman and Wilson; this note corrects this misinterpretation by explaining the data and the experimental set-up in a little more detail.

L. Porter, "Diffraction by a Transparent Elliptical Cylinder", published in Electromagnetic Wave Theory, Proceedings of the URSI Symposium held at Delft, The Netherlands, 1965. Published by Pergamon Press 1967.

The diffraction of an acoustic pulse from a line source by a transparent elliptical cylinder is treated as a formal boundary-value problem. The solutions interior and exterior to the cylinder are represented in terms of eigenfunction expansions of Mathieu functions. Perturbation theory is used to eliminate the difficulty arising from the absence of an orthogonality relation between the angular functions for

the interior and exterior regions of the cylinder. A general asymptotic expression valid for short times after the arrival of the wave front is given for the reflected, transmitted, and diffracted pulses.

B. ELECTROMAGNETICS

H. Berger and J. W. E. Griemsmann, "Guided Waves in Moving Dispersive Media. Part I: Nonrelativistic Velocities; Part II: Relativistic Velocities" * published in the IEEE Transactions on MTT, Vol. MTT-16, No. 1, January 1968.

Part I: A theoretical examination is presented of the influence of a dispersive medium on the time-harmonic TE and TM modal field structure of electromagnetic waves in a cylindrical waveguide of arbitrary cross section when the medium is in relative motion with respect to the waveguide walls. The modal field structure observed both in the reference frame F' attached to the medium, and in the reference frame F attached to the waveguide walls, is determined in closed form. The results presented for the modal fields observed in F are valid when the medium moves with nonrelativistic speed v .

Contact is made with the standard relativistic discussion of TEM waves in slowly moving dispersive media involving the Fresnel drag coefficient, and it is noted that the customary restrictions on v for numerical accuracy of the results can be inadequate. The theory is applied to two special cases.

The nonreciprocal phase shift exhibited by a waveguide filled with moving media is also discussed.

Part II: The detailed modal field structure has been determined for electromagnetic waves propagating in a uniform cylindrical lossless waveguide of arbitrary cross section filled with a moving medium. The medium is assumed to be homogeneous, isotropic, and nondissipative, but may be dispersive. It moves uniformly, with a constant speed v , parallel to the axis of the waveguide. The solutions obtained are exact closed-form functions of the space variables, time, modal wave frequency,

*Work was done in part under Contract No. AF-49(638)-1402.

and propagation factor, and they hold for any value of the magnitude of v , from zero up to the speed of light in vacuum.

The electromagnetic power flow in the waveguide is investigated and shown to display characteristics that differ considerably from those associated with the stationary medium case. The general theory is applied to several types of moving media, including nondispersive media and the idealized low-temperature plasma.

H. Berger and J. W. E. Griemsmann, "The Relativistic Doppler Equations for Attenuated Waves and the Drag Effect".* to be published in the Journal of Applied Physics, July 1968.

A uniform plane, electromagnetic wave which is attenuated as it travels through a dispersive, homogeneous, isotropic medium is demonstrated to have a phase which is not Lorentz invariant. The attenuation can be caused by dissipation in the medium, or because the frequency of the wave is below cut-off frequency of the medium. A generalized set of relativistic Doppler equations for the attenuated plane waves are derived and used to study some of the general properties of this wave. It is shown from the Doppler equations that an attenuated wave which is time-harmonic in one inertial reference frame is not time-harmonic in all other inertial reference frames. This result has important consequences in the formulation of the constitutive relations which characterize the medium. The Doppler equations are also utilized as a basis for studying the drag effect for attenuated waves in moving media. The basic method of analysis in this paper utilizes the rigorous electromagnetic field equations in conjunction with Minkowski's extension of the theory of Special Relativity for material media.

F. M. Labianca, "On Waves Circulating Around a Rigid Cylindrical Obstacle in a Compressible Plasma"**, to be published in Radio Science, Vol. 3 (New Series), No. 8, August 1968.

This paper is concerned with the excitation of electromagnetic (optical) and pressure (acoustical) creeping waves on an infinite perfectly conducting circular cylinder immersed in a compressible plasma.

*Work was done in part under Contract No. AF-49(638)-1402.

**Work was done in part under Contract No. AF-19(628)-2357.

The problem is virtually the same as that treated by Wait (1965). However, the formulation is different from Wait's and lends itself more readily to a ray-optical interpretation (via asymptotic analysis), thereby emphasizing the coupling mechanism between the optical and acoustic fields.

E. Ott, "Electromagnetic Pulse Propagation in Lossless, Inhomogeneous, Dispersive, Dielectric Media", to be published in the Journal of Applied Physics, Vol. 38, No. 12, November 1967.

This paper develops geometrical optics ray techniques for problems of transient electromagnetic wave propagation in inhomogeneous, lossless, dispersive, dielectric media. The method results in a series expansion of the fields about the wavefronts. The theory is applied to solve a few illustrative problems dealing with wave propagation in a cold isotropic plasma. Special attention is given to the fact that in all physical media the wavefronts must propagate at the speed of light in vacuum. This physical requirement does not seem to have been incorporated into the mathematical models used in previous works dealing with geometrical optics techniques for solving transient electromagnetic wave problems.

E. Ott and J. Shmoy, "Transient Aspects of Transition Radiation", published in the Quarterly of Applied Mathematics, Vol. XXV, No. 4, January 1968.

When a charged particle moving at uniform velocity crosses a boundary between two media with different electrical properties, a pulse of electromagnetic energy is emitted. This phenomenon is basically unlike either bremsstrahlung or the Cerenkov effect in that the charge will radiate even though it does not accelerate or move faster than the phase velocity of light in the medium.

Various theoretical¹ and experimental² aspects of transition radiation have recently been the subject of extensive study. It has been proposed that the effect might be useful in the generation of microwave power and as a diagnostic tool for the study of metals and plasmas.

It is clear that the effect is fundamentally a transient process. It is, therefore surprising that the transient character of the fields has hardly received notice. Previous investigators have concentrated on determining the frequency spectrum of the radiation fields. We, on the other hand, will deal directly with the problem of finding the fields as a function of time.

In order to illustrate the essential characteristics of the processes involved, a specific problem will be considered. For the problem selected an exact closed form solution is obtained in a form amenable to physical interpretation. It is found that before the time of impact the entire field may be represented in terms of an image picture, which is a generalization of the static case. Even after impact the image picture remains valid, but only in certain regions of space. At impact, a sudden burst of energy is liberated. This energy then propagates outward from the impact point in a manner to be discussed later. It is to be expected that the solution of the present problem will aid in the understanding of transition radiation in more complicated configurations, for which no closed form solution is available.

The method used to evaluate the transient is patterned after that given by Felsen³. A representation of the solution in terms of Fourier integrals will be obtained; these will then be reduced to such a form that they can be evaluated by inspection.

E. Ott and J. Shmoy, "Transition Radiation and the Cerenkov Effect", to be published in the Quarterly of Applied Mathematics.

The analysis of transient radiation emitted by a line charge moving at a constant velocity at right angles both to itself and to a plane interface between two dielectric half-spaces has been generalized to include the possibility of Cerenkov emission in either medium. Just as in the special case of charge velocity lower than the wave velocity in either medium, the exact solution of the problem is obtained, but with additional pole contributions. The wavefront configuration corresponding to various relative values of the three velocities is obtained and discussed. In particular, the build-up of Cerenkov radiation as the line charge enters a medium with sufficiently high dielectric constant is studied.

E. Ott and J. Shmoys, "Transient Radiation in a Plane Stratified Dispersive Medium. I. Half-Space Configuration", published in the Canadian Journal of Physics, Vol. 46 (1968).

In this paper a similarity principle will be derived for a class of transient diffraction problems in cold, lossless, isotropic plane stratified plasmas. The similarity principle will be utilized to obtain an exact closed-form solution to the problem of a magnetic current source whose density is a delta function (in space and time) situated either in or above a homogeneous plasma half-space. This solution will be interpreted in terms of rays and group velocity. An independent solution to the half-space problem will also be obtained using asymptotic techniques. Exact and asymptotic solutions will be compared and discussed.

C. PLASMAS

H. W. Friedman, "Nonlinear Asymptotic Analysis of the Positive Column", published in The Physics of Fluids, Vol. 10, No. 9, September 1967.

The positive column of a slightly ionized gas discharge confined by cold, insulating walls is described by a set of nonlinear fluid equations. The inertia, space charge, and collision terms are retained. A zeroth-order solution uniformly convergent to the exact solution in both plasma and sheath regions is derived using asymptotic boundary-layer analysis. The value of potential at the wall is calculated by means of a kinetic model. It is found that the density at the wall can be a significant fraction of the value at the center and that it vanishes only in the low electron temperature limit. The original Bohm criterion is recovered as a necessary condition for sheath stability and is interpreted to mean that the ambipolar sound speed (1) asymptotically separates the plasma from the sheath, and (2) is the maximum ambipolar diffusion velocity.

H. Friedman and E. Levi, "Singularities of the Fluid Equations and Their Relation to Anomalous Diffusion", published in The Physics of Fluids, Vol. 11, No. 3, March 1968.

The nonlinear equations governing the diffusion of magnetized plasmas do not admit steady-state solutions when the magnetic field

intensity exceeds a critical value. This may explain the onset of instabilities leading to anomalous diffusion.

K. Stuart and E. Levi, "Observation of Resistive Instabilities in a Toroidal Plasma", to be published in the Journal of Applied Physics, Vol. 39, No. 6, June 1968.

An experiment is described in which resistive instabilities have been observed. Diagnostics of a hydrogen toroidal plasma indicate that a current varying plasma sheet breaks up into separate filaments. Experimental data for three distinct filament configurations agree well with the theoretical predictions.

III. ARPA-RELATED ACTIVITIES, LECTURES, CONSULTANTS, PAPERS SUBMITTED TO OUTSIDE JOURNALS, AND INTERNAL REPORTS

A. ARPA-RELATED ACTIVITIES

Dean Martin H. Bloom is a member of the Atomic and Molecular Physics Panel of the Institute for Defense Analyses (IDA).

Dean Bloom is Associate Editor of the Journal of Ballistic Missile Defense Research, published by IDA for ARPA.

Professor Leopold B. Felsen is a member of a special sub-panel of the Arecibo Ionospheric Observatory (AIO) Evaluation Panel.

Participation at meetings relevant to the program included the following talks:

October 1967:

- a) Conference on Application of Plasma Studies to Re-Entry Vehicle Communications at Wright-Patterson Air Force Base, Dayton, Ohio:

J. W. E. Griemsmann	R. G. E. Hutter	S. Lederman
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- b) ARPA Institutes Fiscal Review, The Pentagon, Washington, D. C.:

M. H. Bloom	F. R. Eirich	R. G. E. Hutter
R. J. Cresci	L. B. Felsen	E. Levi
	J. Fox	

- c) M. H. Bloom conferred with Mr. McLain and Dr. S. Scala on "Time Dependent Flow Field Analysis"; also visited ARPA, both meetings at The Pentagon, Washington, D. C.
- d) Several members of the Department of Electrophysics of PIB presented papers at the meetings of URSI as well as the IEEE Group on Antennas and Propagation, held at the University of Michigan at Ann Arbor. Among these presentations was a paper by A. Hessel, G. Knittel and A. A. Oliner entitled "On the Theory of Resonances in Phased Array Antennas".
- e) M. H. Bloom attended the Wake Quench/Seed Specialists' Meeting at the Aerospace Corporation, San Bernardino, California, and the AIAA Organizing Committee Meeting held in Anaheim, Calif.
- f) L. B. Felsen visited Cambridge University, Cambridge, England and discussed problems in Plasmas and Ionospheric Propagation with Drs. P. C. Clemmow and K. G. Budden.

November 1967:

- g) ARPA-IDA Conference on Turbulence Experiments and Flow Field Calculations. Meetings were held at ARPA and IDA, Washington.
M. H. Bloom G. Moretti
- h) M. H. Bloom presented a lecture at a Colloquium at the University of Pennsylvania, Philadelphia, entitled "Aerodynamics at High Altitudes: Review and Extensions".
- i) J. T. LaTourrette attended the 24th Anti-Missile Research Advisory Council (AMRAC) Meeting at the USN Postgraduate School in Monterey, Calif.
- j) K. Chung presented a paper entitled "Decay Process in the Afterglow Cathode Discharge Arc Plasma" (co-authors: D. Ross and D. J. Rose), at the Annual Meeting of the Division of Plasma Physics, American Physical Society, Austin, Texas.
- k) D. S. Wilson presented "Theory and Experiments on Precursor Ionization in a Pressure Driven Shock Tube" (co-authors: S. Lederman and T. Lin), at the American Physical Society Fluid Dynamics Meeting in Bethlehem, Pa.
- l) E. L. Rubin visited the Institute for Defense Analyses, Arlington, Va. for a meeting with Dr. J. Menkes.

December 1967:

- m) D. S. Wilson had a discussion with R. Vaglio-Laurin and M. Hoffert at New York University on the Precursor Problem and Temperature of Precursor Electrons.
- n) Mr. Kent Kresa, Program Manager of BMD, ARPA, Washington, visited Dean M. H. Bloom and others at the Long Island Graduate Center of PIB.

- o) Dr. Peter Franken, Director of ARPA at The Pentagon visited Professor G. Gould at the Long Island Graduate Center.
- p) M. H. Bloom conferred with Col. R. M. Dowe and Mr. K. Kresa; also with Mr. J. Persh and Mr. MacArthur of the Office of the Director of Defense Research and Engineering, to discuss materials problems. These meetings were at The Pentagon.

January 1968:

- q) M. H. Bloom visited the Institute for Defense Analyses in Arlington, Va. for discussion of research program and relationship to classified ARPA objectives.
- r) AIAA 6th Aerospace Sciences Meeting held in New York City:
M. H. Bloom presented a paper entitled "Electron Density Distribution in the Near Wake" (co-authors: S. Lederman and G. Widhopf).
S. Lederman presented "Experiments on Cylindrical Electrostatic Probes in Slightly Ionized Hypersonic Flow" (co-authors: M. H. Bloom and G. Widhopf).
Other attendees: B. Grossman M. Pierucci E. M. Schmidt
- s) A seminar in "Strong Interactions in Aerodynamics" sponsored by the American Institute of Aeronautics and Astronautics Professional Study Series in New York City. The instructors were M. H. Bloom and S. G. Rubin.
- t) BMD Meeting held in Washington, D. C.
J. W. E. Griemsmann E. Levi
- u) M. H. Bloom and R. J. Cresci participated in the "On-Board Measurements Workshop" at JILA, Boulder, Colorado.
- v) D. S. Wilson presented "Precursor Ionization in a Pressure Driven Shock Tube and Its Relevance to the Re-Entry Problem" at Bell Telephone Laboratories, Whippany, N. J.

February 1968:

- w) M. H. Bloom presented a seminar on "Interaction Aerodynamics" at Syracuse University, Department of Mechanical and Aerospace Engineering.
- x) R. J. Cresci gave a seminar on " 'Slingshot' - An Advanced Test Facility" at the Naval Ordnance Laboratory, White Oak, Md.
- y) S. Lederman presented a talk entitled "Plasma Diagnostics by Means of Microwaves and Electrostatic Probes" at New York University.
- z) L. B. Felsen and E. Levi visited Drs. Marple and Bern at the Riverside Research Laboratory in New York City for discussion of work on scattering from wakes.

March 1968:

- aa) M. H. Bloom and S. H. Rubin presented a lecture series on "Strong Interaction in Aerodynamics" at NASA, Langley Field, Va.
- bb) Visit to Professor J. Jarem at Drexel Institute of Technology, Philadelphia, Pa. for discussion on electromagnetic scattering from missile wakes:

L. B. Felsen
E. Levi
S. Rosenbaum
- cc) E. Levi attended at Ballistic Missile Defense Meeting at The Pentagon, Washington, D. C.
- dd) M. H. Bloom visited the Office of the Director of Defense Research and Engineering at The Pentagon for a conference on re-entry vehicles.

Meetings to be held in April:

PIB Symposium on Turbulence of Fluids and Plasmas

Annual ARPA Institutes Review Meeting (Host: Polytechnic Institute of Brooklyn)

B. LECTURES

There have been many formal seminars and informal discussion groups; a partial listing is given here:

October 1967:

I. Haber	An Experiment to Measure Transition Radiation in Gaseous Plasma
H. Derfler Institute for Plasma Research Stanford University, Calif.	Instabilities in Plasmas
C. Shih	Problems connected to "Low Frequency Confinement of a Plasma Column"
G. Moretti	Numerical Experiments on Time-Dependent Techniques for Steady Inviscid Flows
J. Pirraglia	Clarification of Cyclotron Damping
R. Chimenti	Spectroscopic Study of a Toroidal Discharge
K. Stuart	Experimental Observation of Resistive Instabilities in a Toroidal Plasma

Sir Geoffrey I. Taylor
Cambridge University
Cambridge, England

Some Recent Work in Electrohydrodynamics

November 1967:

P. Rabinowitz

Laser Plasma Diagnostics

R. A. Gross
Columbia University
New York, N. Y.

The Physics of Strong Shock Waves

E. Torrero

The Equivalent Dielectric Tensor of Plasma

B. Riley Tripp
Head, Electronics Tech-
niques Section
Cornell Aeronautical Lab.
Buffalo, N. Y.

Scattering of Electromagnetic Waves from
Plasmas

N. H. Lazar
Thermonuclear Div.
Oak Ridge National Lab.
Oak Ridge, Tenn.

The Use of a Target Plasma in High Energy
Injection Experiments

December 1967:

E. Levi

Singularities in the Fluid Dynamic and
Vlasov Equations

K. Chung

Characteristics of Hollow Cathode Discharge
Plasma and its Weak Turbulent Spectra

Bernard Eastlund
Controlled Thermonuclear
Research Program
U.S. Atomic Energy Comm.

Cerenkov Radiation in Plasma

L. Silverstein

Laser Heating of Plasmas, Part I

K. Stewartson
Ohio State University and
University of London

Hypersonic Boundary Layers

J. Bach Andersen

Coupling Between Electrostatic and Electro-
magnetic Waves on Plasma Columns

L. Silverstein

Laser Heating of Plasmas, Part II

January 1968:

- | | |
|---|--|
| R. Hutter
H. Farber | Development of a Beam Plasma Amplifier |
| B. Singer
Raytheon Laboratories
Stamford, Conn. | Radiation from a Source in a Periodically-Stratified Medium, Part I |
| A. Oppenheim | Bremsstrahlung in Plasmas |
| B. Singer
Raytheon Laboratories
Stamford, Conn. | Radiation from a Source in a Periodically-Stratified Medium, Part II |
| A. Bers
Department of Electrical
Engineering and
Research Laboratory of
Electronics
Massachusetts Institute of Technology
Cambridge, Mass. | Stability Criteria and Analysis for Plasmas and Dispersive Media |
| R. E. Barrington
Defence Research Telecommunications
Establishment
Defence Research Board
Department of National Defence
Shirley Bay, Ottawa, Canada | Very Low Frequency Waves Observed in the Ionosphere |

February 1968:

- | | |
|--|--|
| W. Grossman
Richmond College
City University of New York
New York, N. Y. | Two Dimensional High- β Equilibrium in Mirror Devices |
| K. Chung | Study of Unstable Electrostatic Ion Cyclotron Mode - A Preliminary Description |
| Leon N. Zadoff
Fairchild-Hiller Corp.
Republic Aviation Div.
Farmingdale, N. Y. | Resistive Instabilities of a Viscous Fluid |
| E. L. Rubin | Topics in the Numerical Calculation of Time-Dependent Shocked Flows, Part I |
| J. Jarem
Head, Department of Elec-
trical Engineering
Drexel Institute of Technology
Philadelphia, Pa. | Electromagnetic Scattering from Random Surfaces |

March 1968:

E. L. Rubin	Topics in the Numerical Calculation of Time-Dependent Shocked Flows, Part II
F. Stone	Multi-Stream Approach to Instabilities in Beam-Magnetoplasma Systems
E. L. Rubin	Topics in the Numerical Calculation of Time-Dependent Shocked Flows, Part III
I. Haber	Transition Radiation in an Inhomogeneous Plasma
P. Serafim	Quasi-Linear Theory of Plasmas in Magneto-static Fields

During the course of this six-month period, Dr. Nathan Marcuvitz (of NYU) presented a lecture series on Plasma Turbulence.

C. CONSULTANTS

Dr. Nathan Marcuvitz of New York University.

D. PAPERS SUBMITTED TO OUTSIDE JOURNALS

- Berger, H. and J. W. E. Griemsmann, "Complex Doppler Effect in Dispersive Media", submitted to the Journal of the Optical Society.
- Chimenti, R., "A Sampling Technique for Time-Resolved Spectroscopy", submitted to the Review of Scientific Instruments.
- Dorman, G., "Interaction of a Relativistic Electron Beam with an Inhomogeneous Plasma", submitted to the Journal of Plasma Physics.
- Sforza, P. M., "Some Preliminary Experiments on Probe Interference in Hypersonic Near Wakes", submitted to the AIAA Journal.
- Stuart, K. and E. Levi, "Observation of Rayleigh-Taylor Instabilities", submitted to the Journal of Applied Physics.
- Stuart, K. and E. Levi, "Observation of Resistive Instabilities in a Toroidal Plasma", submitted to the Journal of Applied Physics.

E. INTERNAL REPORTS

Wilson, D. S. and T. C. Lin, "Impurity Photoionization Theory of Precursors", PIBAL Report No. 1006, Department of Aerospace Engineering and Applied Mathematics, Polytech. Inst. of Brooklyn, October 1967.

Schmidt, E. M. and R. J. Cresci, "An Experimental Investigation of Hypersonic Flow Around a Slender Cone", PIBAL Report No. 1031, Department of Aerospace Engineering and Applied Mathematics, Polytech. Inst. of Brooklyn, October 1967.

Wilson, D. S. and S. Lederman, "Precursor Ionization Due to Photoionization of H_2 Impurities in Argon Shocks", PIBAL Report No. 1033, Department of Aerospace Engineering and Applied Mathematics, Polytech. Inst. of Brooklyn, November 1967.

Cresci, R. J. and E. M. Schmidt, "Near Wake Measurements in the Presence of an Instrumentation Boom", PIBAL Report No. 1034, Department of Aerospace Engineering and Applied Mathematics, Polytech. Inst. of Brooklyn, November 1967.

Koga, T., "A Kinetic (Non-Linear) Theory of Turbulence in Incompressible Fluids", PIBAL Report No. 68-5, Department of Aerospace Engineering and Applied Mathematics, Polytech. Inst. of Brooklyn, March 1968.

Koga, T., "Derivation of the Boltzmann Equation as a Test Case of Kinetic-Theoretical Schemes", PIBAL Report No. 68-7, Department of Aerospace Engineering and Applied Mathematics, Polytech. Inst. of Brooklyn, March 1968.

Coordinated by R. Hutter, "Research on Electromagnetics for Project DEFENDER", Semi-Annual Technical Summary for the period ending 30 September 1967, PIBMRI-1295.5-67.

Stuart, K., "Experiments on Resistive Instabilities in a Toroidal Plasma", PIBMRI-1379-67, Department of Electrophysics, Polytech. Inst. of Brooklyn, December 1967.

Griemsmann, J. W. E., A preliminary report entitled "Plasma Distribution Effects on Diagnostics of a Plasma Cylinder - Surface Impedance Effects", PIB EP-68-003, Department of Electrophysics, Polytech. Inst. of Brooklyn, February 1968.

IV. PERSONNEL

Y. Avidor	Research Assistant
M. H. Bloom	Professor Dean of Engineering Director, Gas Dynamics Research
K. Chung	Associate Professor
R. J. Cresci	Professor
E. Dawson	Research Assistant
H. Farber	Associate Professor
L. B. Felsen	Professor
J. W. E. Griemsmann	Professor
R. G. E. Hutter	Professor Principal Investigator
D. Jacenko	Research Associate
K. R. Jolls	Assistant Professor
S. Lederman	Associate Professor
E. Levi	Professor
J. Librizzi	Research Assistant
E. Malloy	Research Assistant
G. Moretti	Professor
A. Pal	Assistant Professor
R. Pepper	Research Associate
M. Pierucci	Research Associate
P. Sasman	Research Associate
E. Schmidt	Research Associate
P. E. Serafim	Assistant Professor
P. Sforza	Assistant Professor
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G. Widhopf	Research Assistant
D. S. Wilson	Assistant Professor

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